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The news of the death of Dr. Goldie at Stirling on 24 January 1964, at the age of 75, came as a great shock to past and present members of the Office who knew him. Soon after his retirement nearly eleven years ago he moved back to the land of his birth and his many friends hoped he would find contentment there for many years to come. Unfortunately the later years of his retirement were marred by ill-health and that this should eventually have led to his death is, indeed, very sad.

Dr. Goldie joined the Meteorological Office as a Junior Professional Assistant in August 1913 and during his first two years in the Office he served at Falmouth Observatory, at South Farnborough and at Eskdalemuir Observatory. In September 1915 he was commissioned in the Meteorological Section of the Royal Engineers in which he served for four years and attained the rank of Major. He returned to the Office in 1919 and spent the next four years as Superintendent of the Local Services Division which catered primarily for the needs of the RAF. Then followed fourteen years as Superintendent of the Meteorological Office, Edinburgh, and nine years as Assistant Director responsible for research and in charge of the Marine, Climatological and Instrument branches. Finally, for the last five of his forty years' service he was Deputy Director for Research. A more detailed account of his career in the Office was published in the Meteorological Magazine for June 1953, shortly after his retirement.

Dr. Goldie was a good example of that comparatively rare combination of research scientist and sound administrator. He was thus well suited for the task of organizing research within the Office and for the official administration of the Meteorological Research Committee; but in addition to the work that this entailed he undertook personal research of high quality. His published papers cover a wide variety of important subjects, such as the general circulation of the atmosphere, the physics of the formation of condensation trails (of great importance during the Second World War), and the electrical conditions in the high atmosphere producing geomagnetic storms.

By nature Dr. Goldie was a quiet and friendly man who was highly esteemed by all who worked with and for him. When he took charge of the Marine, Climatological and Instrument branches on their evacuation to Stonehouse, Gloucestershire, he and his first wife, formerly Miss Marion Wilson of the staff of the Meteorological Office, Edinburgh, devoted much effort to ensure the welfare of all members of the staff under the difficulties of living and working as evacuees. Many must look back with nostalgia at the pleasant Sunday afternoon gatherings at the old Cotswold house which the Goldies temporarily occupied at Woodchester. The news of Mrs. Goldie's death in 1948 came as a great sorrow.

In 1952, to the great pleasure of all their colleagues, Dr. Goldie married Miss Helen Carruthers who was on the scientific staff of the Climatology Division. The deep sympathy of those of the Office who knew her husband goes to Mrs. Goldie in her sad bereavement.

F. J. SCRASE

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METEOROLOGICAL OFFICE DISCUSSION

Longe-range weather forecasting in Great Britain

By J. M. CRADDOCK

The 3rd Monday Discussion of the 1963/64 season was held in the rooms of the Royal Society of Arts on 20 January 1964 under the Chairmanship of Dr. R. C. Sutcliffe. Mr. J. M. Craddock presented the following account of work on long-range forecasting which has taken place in the Meteorological Office since 1953.

Introduction.—Research work concerned with the slower changes in the atmosphere is at the stage typified by Kepler rather than Newton, in that its main task is that of assembling facts and recognizing regularities and patterns rather than seeking explanations. The phenomena considered are long lasting and cover wide geographical areas, while meteorological observations on a corresponding scale are comparatively recent, with the result that the number of adequately documented cases is far less than the number required as the basis for firm conclusions. Even when the utmost use is made of the incomplete observations made since the earliest times, the most serious restriction on the intending long-range forecaster is the shortage, not of ideas, but of information.

The general approach.—Our general meteorological experience leads us to the view that the large-scale processes control the smaller, and that our future weather depends, not so much on past and present conditions in Great Britain, as on the large-scale workings of the general atmospheric circulation. We must be prepared to study changes over an area at least as large as that used by the short-range forecaster, but unlike him we must average or filter our data to minimize the short-lived features which dominate the daily synoptic chart while preserving the more lasting though often smaller features which may persist further into the future. This involves a routine of rather mechanical calculation.

Once we have our current data prepared in a way which emphasizes the more lasting features, we require a library of past cases prepared in the same way, for use directly as analogues of the current situation, or indirectly to find rules and patterns of behaviour which may be applied to the future. In any case, the value of our conclusions will be in proportion to the size, relevance and comprehensiveness of our backing library. Often a suggestion which looks reasonable on theoretical grounds, or by reference to a small selection of past cases, can be seen at once to be unjustified when considered in the light of a comprehensive library of past cases. The assembly of the best possible library is a very large task, entailing the collection and collation of data from many sources, and their presentation in a form suitable for ready reference and easy assimilation.

Theoretical considerations.—Any attempt to treat the slower atmospheric processes from general physical principles must take account of the thermodynamic processes which result in heat received from the sun near the equator being transferred polewards to balance radiative losses in high latitudes. While attempts at a theoretical solution have been made, e.g. by Smagorinsky[1] and Adem[2] it is doubtful whether present knowledge can yet produce a model which is simple enough for regular use but complicated enough to be realistic. In any case our observations are so incomplete, particularly in the tropics and in and over the oceans, that I doubt whether we can specify the initial conditions accurately enough to start a thermodynamic model on the right lines. An approach from direct physical principles is for the future rather than the present.

On the other hand, a purely statistical approach has to deal with material which does not conform to any of the familiar statistical patterns. Most meteorological variables show some periodic variations related to a basic period of a year. The periodic component can be estimated in advance from past values of the variable concerned, and this estimate which may be called the normal, or climatic expectation, is generally taken as a first approximation to a future value. The long-range forecaster has to try to improve on this by forecasting the departure from normal in the individual year in terms of observed departures from normal up to the time the forecast is made. If these departures from normal are measured, say at daily intervals, it generally appears that they do not occur haphazardly, but on the other hand they do not follow any regular periodic pattern. They usually form a coherent, vaguely oscillatory time series; a time series, moreover, in which the statistical characteristics are liable to vary with time, either erratically, or in a manner depending on the time of year.

These departures from normal are also subject to spatial correlations and geographical constraints in a way which is familiar to meteorologists but less so to most statisticians. Often, when data are arrayed for use in a table or chart, the number of data required for adequate representation is far greater than the number of effectively independent data, so that statistics calculated from such a field appear to be far more reliable than they really are.

These remarks help to show why simple statistical methods of the kind used extensively by Sir Gilbert Walker[3] have almost always produced disappointing results.

Having mentioned these difficulties, which render the field an unattractive one to many scientists, we must remember that many operations of agriculture and industry have to be planned well in advance in the light of the expected weather, which in the absence of any long-range forecast will be assumed to be the climatic normal. Any system of long-range forecasting will be useful provided that the errors of the forecasts are on average less than those which result from using the climatic normal on every occasion.

In these circumstances our object has been to develop a series of techniques, each with some physical argument in its favour, and supported by the fullest possible backing library of past instances. Now, although no one method produces useful indications all the time, we sometimes get strong indications from several methods suggesting a departure from normal in a particular direction. On other occasions the indications may be so weak and conflicting that we can only forecast the climatic normal.

Temperature anomaly patterns.—Our first experiment consisted of the preparation as a routine of 5-day mean charts of the anomaly of air temperature at the earth's surface over an area of the northern hemisphere extending from the Rocky Mountains to beyond the Urals. The groundwork leading to the estimation of the normals from which these anomalies are measured has been described by Craddock[4] and the first 5-day mean temperature anomaly chart was for 1 to 5 May 1955. From 1957 pressure anomaly charts were produced as well, and both the series were continued until Autumn 1963, when they were superseded by charts—covering a larger area—of the 5-day mean anomalies of 1000-500 mb thickness and 1000 mb contour height.

Examination of the large-scale patterns of temperature anomaly showed that these were surprisingly well marked and persistent, and furthermore that they agreed with few exceptions with the anomalies of thickness of the 1000-500 mb layer. Since these anomalies are strongly correlated with those of the 500 mb airflow, we may be able to use the pattern of the anomalies of air temperature near the earth's surface as an indicator of the state of the circulation in the upper troposphere. If the present state of the circulation in the upper troposphere is any indication of the future, then cases which are similar in their large-scale patterns of temperature anomaly should tend to evolve in the same way. This hypothesis has provided our first experimental method for long-range forecasting, described in detail by Craddock.[5] The essentials are that our current 5-day mean charts are averaged towards the end of each month, to provide an approximation to the temperature anomaly pattern for that month. This pattern is compared with similar patterns for the same calendar month for all past years back to 1881, the most similar patterns are chosen as analogues, and the actual developments in the analogue years are used as basis for a forecast for the month to come, with more or less confidence depending on the agreement found between the sequels in the various analogue years.

We soon found that a large-scale similarity in the temperature anomaly fields is not in itself enough to produce a reliable basis for prediction, and we added the further conditions that there must be some agreement in the neighbourhood of the British Isles and in the sequence of weather types affecting the same limited area. With these additions, the technique is still in use, and is indeed, the only technique which has been used for long enough to enable us to get any real knowledge of its performance. It appears to work best in summer and worst in spring and autumn; it has had runs of months showing an encouraging standard of success but also, in 1959, a long run of almost unmitigated failure, and it appears, going over past results, that the standard of success would have been higher if, instead of forecasting for every month, we had only made forecasts in those months, amounting to perhaps one third of the total, in which the indications before the event seemed strongest.

The fact that it took us eight years to find the field of usefulness of this one technique emphasizes the point that this is a subject on which knowledge will grow very slowly as long as every new idea has to be tested against future data. If new ideas can be tested against past data we can decide more quickly if they are useful. Tests of this kind have been carried out by ourselves, by Šiškov[6] in the U.S.S.R. and by other workers elsewhere. However, because a single forecast, made by a particular technique, occupies a panel of human forecasters for two or three hours, it is difficult to stage an experiment for testing the method on past data on a scale large enough to be really convincing.

It is worth mentioning that the staging of this experiment entailed the preparation of a backing library of about 1000 charts, each plotted with perhaps 200 temperature anomalies, one chart for each month from January 1881 up to date. A similar experiment could be based on charts of the monthly mean pressure anomaly pattern, but this would require another backing library of about the same size. We have made some progress towards this, because we have obtained from German and American sources photographic copies of charts of the monthly mean pressure for each month from January 1873 up to date, and of the pressure anomaly for each month of the years 1901 to 1937. Further, for the months of January and July only we have the use of pressure charts since 1750 produced by Mr. H. H. Lamb[7] for use in the study of climatic change. The conversion of these charts to a scale and projection comparable with our current working charts is an example of the time-consuming operations which must be carried out before full use can be made of our current data.

Analogues by computer.—The development and testing of forecasting methods can be enormously accelerated if instead of carrying out the processes of analogue selection by hand, we can perform the process on an electronic computer. Moreover, since the selection techniques are embodied in fixed, numerical rules, they are quite objective and free from the variations in standard which human forecasters find so hard to avoid. On the other hand, the computer has no commonsense and can only follow instructions, so that we must make very sure that we provide for every eventuality, and that we understand the full import of each instruction we give. This involves testing each step carefully before going on to the next.

From the time in 1957 when we knew the Meteorological Office was going to have a computer we started to build up a backing library on paper tape which could be fed into the computer. Many data we acquired from the meteorological services of the United States and Western Germany in the form of punched cards. Other data, including most of the Smithsonian *World Weather Records* were punched on to cards by other branches of the British Government Service. These all had to be converted to paper tape by means of a mechanical converter. We also punched data direct on to tape for ourselves. In spite of delays, we have built up over the years an impressive library of data in a form suitable for input to the computer.

Programming for the computer was shared by Mr. M. Grimmer and myself and nearly all the work on the matching of temperature anomaly patterns by computer was carried out by him. The first problem is to decide on a method of measuring the similarity between two charts which gives sensible results. Assuming each chart is represented by the values at a fixed grid of points (78 in our case) we have somehow to sum the discrepancies at all the points to measure the overall discrepancy. Then we can match the current chart against each of those for the same month in earlier years, and choose the most similar. The methods of matching used were the mean square discrepancy, the mean Bagrov index (see Bagrov and Morskoj[8]), the correlation coefficient, a measure of agreement in sign, and a system in which all anomalies are classified into five categories and more marks are given the closer the corresponding values are to each other. None of these always gave sensible results, but an analogue selected by several methods is more likely to appear good to a human observer than one selected by one method only, and what is more important, it seems to have an above average chance of producing a good forecast. Another method of analogue selection depends on representing each chart by means of empirical orthogonal functions, in the way described by Grimmer.[9] The analogues chosen are the cases which show best agreement in the coefficients of the more important functions. Lists of analogues produced by several variants of these objective methods are produced by computer every month, and form part of the evidence considered by the panels of forecasters who actually do our long-range forecasting.

These objective methods are, of course, excellent for trial on past data, and Mr. Grimmer did in fact carry out several very large experiments to find the best methods of application. This work is still incomplete, and I need only say the standard of success may be highly significant, or it may be negligible, depending on the conditions of the experiment.

At the same time I was examining the conditions under which the temperature anomaly in one month provides valid evidence about the anomaly to be expected in another. This work has been described by Craddock and Ward[10] and the results occasionally provide a useful indication to the long-range forecaster.

Sequence analogues.—About this time the transfer of the long-range unit to the Climatological Research Branch, which took place as soon as the two units were moved to the new headquarters building at Bracknell, led to an influx of new material and new ideas, largely contributed by Mr. H. H. Lamb. The most important source of material is a classification (as yet unpublished), made by Mr. Lamb or his assistants, of the weather type over the British Isles for each day of each year from 1873 up to date. Using this valuable addition to our backing library, it is possible to select subjectively the weather sequences in past months or other periods which most resemble those of the period just completed, and this method of selecting analogues was at once included in our monthly routine.

The next stage was to select sequence analogues by computer. Before this could be done we translated Lamb's classification into a letter code in which each weather type is represented by one letter, so that, for example, a group of 31 letters will represent unambiguously the weather of each day of a 31-day month. This translation made it easy to read the data into the computer, and incidentally, made it possible to produce copies of the classification on the teleprinter. The task of devising an objective method of matching coded weather sequences proved less formidable than I had expected, and analogues selected by three objective methods of comparison are also included in our monthly routine.

While this was being done, Mr. R. Ward set out to produce his own classification of the daily and 5-day mean weather at London from 1873 up till now. This has a more local application than Lamb's classification, as the weather types are based on the direction of the geostrophic airflow in the 1000 miles before it passed over London, and on the pressure level at London.

This classification has also been coded for the computer and is used to produce objective lists of analogues. These methods of sequence matching can be carried out for periods longer or shorter than the calendar month, or for a 30-day period starting in mid-month, and are indeed our most useful tools for the production of forecasts starting in mid-month.

Forecasting routine.—The most recent charts of temperature and pressure anomaly are considered towards the end of each month by a panel of forecasters who select a group of analogues subjectively by comparison with the charts for the same calendar month since 1881 for temperature and since 1873 for pressure. Sequence analogues are chosen from the years since 1873. These lists are then compared with similar lists produced objectively by computer, and differences between the lists are reconsidered. The object of the list is to discover several past years which are similar to the present year under several headings, rather than years showing strong resemblance under one heading but little under any other. The selected years usually number from four to eight and the daily charts for the appropriate month in these years are re-examined by two pairs of forecasters working independently, and compared with the charts for the current month. This examination may result in some years being thrown out and often results in the analogue years being put in a different order of preference. This conference occupies the greater part of a working day.

A second conference is held, which is intended to take account of any and every other piece of evidence which may be relevant to the issue. It includes consideration of the state of the Arctic ice, the extent of snow cover, and the field of sea temperature anomaly in the North Atlantic and also items such as the forecasting rules proposed by Dr. F. Baur[11] and the month-to-month temperature relationships already mentioned. These arguments do not often by themselves lead to a definite forecast, but they may provide valuable indications when taken in conjunction with the analogues.

The conclusions reached at these conferences are presented at a final conference which normally takes place on the morning of the last day of the month. This conference, at which the final decisions are taken, is attended by officers senior to those who carry out the earlier work; the various indications are reviewed and discussed, and general agreement reached about what conclusions can be justified by the evidence. The final stages include the drafting of the forecast and the routine for printing and dispatch.

A similar but somewhat simpler routine is carried out at mid-month, to produce a forecast running to the middle of the following month.

Verification and checking.—A forecast based on a selection of analogues as indicated above may be in quite general terms (for example that a month is expected to be changeable, but predominantly cold and rainy) which give a clear picture, but are not easy to check. Partly to provide figures for checking, partly to clarify the indications to be drawn from a given group of analogues, Mr. R. Ward and his assistants have carried out the task of classifying the weather elements for a selection of British stations into deciles of the appropriate distribution. These decile values may show, for example, that in each of several analogue months the rainfall was high in the south-east and low in the north-west, or alternatively, that no obvious pattern existed, and the forecast can be phrased to take account of this. For checking purposes the decile values are grouped in pairs into quintiles, and the mark given depends on the difference between the forecast and the observed quintile value at each station. This marking system can be adjusted to suit special requirements, and the version we use is designed so that a forecaster who does not know and is forecasting at random will secure no advantage by forecasting the normal. Another system which we use for comparative markings of our own forecasts and those received from overseas, is a five-point letter marking, from A which means 'no serious discrepancy between forecast and event,' and B 'good agreement,' down to E 'no real resemblance.'

The standard of success achieved depends partly on the checking system, and in view of the radical expansion of our methods during the last 2 years, it is difficult to say what it is. However, each of the main methods used would have had better than chance success if it had been used on each of the appropriate occasions in the last 8 years.

Recent developments.—The severe winter of 1962/63 emphasized the desirability of our being able to draw analogues not only from the recent years which mostly form a relatively mild epoch, but also from the earlier period in which severe winters were more frequent. Fortunately a good deal of work had already been done on the availability and interpretation of early data, by Mr. H. H. Lamb in the study of climatic change and by Craddock and Ward.[10] We found that we have enough data to determine the monthly mean temperature anomaly patterns over a useful area in western and central Europe for any month back to 1770, and the work of extending our reference library backwards from 1881 is now in progress.

The success of the Extended Forecast Branch of the U.S. Weather Bureau in forecasting for the winter of 1962/63 received wide publicity in Great Britain, and in May 1963 I visited Mr. Namias at his Office near Washington to gain first hand acquantance with his methods. I have already given a full account of my visit (see Craddock[12]), so I need not repeat it now, but one conclusion I reached was that their treatment, based on circumpolar charts which covered all longitudes of the northern hemisphere, might easily discover indications which would be missed from our view-point, which had been confined to the Atlantic sector. On my return we considered the possibility of including 5-day mean upper air charts in our working material, and soon found that if we carried out our calculations by computer we would be able to display our material better and effect a saving in manpower.

So in August 1963 we decided to make a major change in our routine; to abandon our 5-day mean charts of temperature and pressure anomaly, which had to be produced by hand, and to use instead charts of the anomaly of 1000–500 mb thickness, 1000 mb contour height and 500 mb contour height, which could be produced by computer. Thanks to efficient use of the computer and outstanding diligence on the part of our staff, the change was completed in something over 2 months.

The value of our new 5-day mean upper air charts will be much increased when we have a library of similar charts for past years for comparison. The production of such a library from daily data would be a colossal task, but we are able to make use of a valuable pack of punched cards received from the West German Meteorological Service. These data are being averaged and rearranged by computer, so that from packs of daily upper air heights arranged by circles of longitude there emerge 5-day mean heights in proper order for plotting on a circumpolar chart. The work, which is still in progress, illustrates the power of the computer at compressing within a few months work which could have taken half a lifetime.

Conclusions.—In the interests of brevity I have not mentioned our own fundamental researches and have said little of the interchange of ideas, forecasts and material which has gone on with meteorological services overseas. In fact the German methods, based on those of Dr. F. Baur (see, e.g. Baur[11]), the American methods described by Mr. J. Namias[13] and the Russian work based on and extending the ideas of B. Multanovskij[14] have all been given a good deal of attention. Work in these countries is proceeding actively, and often with a method of approach not unlike our own.

However, the features of our own work to which I attach most importance are these: firstly, our insistence on the use of objective, computer methods of selection as well as subjective methods; secondly, our use of panels of scientists rather than individuals to take the inescapable subjective decisions, and thirdly, the importance we attach to a comprehensive library of past cases, which enables us to match the current situation from many aspects and to select the best all round precedents rather than cases which are similar only in one respect. Finally I should mention the use of the computer, as a powerful and flexible tool with very varied applications.

In conclusion, our organization for collecting facts relevant to future weather sequences and drawing useful inferences from them will bear comparison with any similar organization in the world, and while I will not speculate on what the attainable standard of success in long-range forecasting may be, I do claim that few organizations have as good a prospect of reaching it as our own.

In the discussion which followed, Mr. R. F. M. Hay produced some results suggesting the possibility of predicting the summer temperatures in Great Britain from spring temperatures in North America and Russia, and Mr. N. E. Davis urged the prognostic value of the 100 mb chart. Mr. H. H. Lamb emphasized the importance of understanding the physical processes involved and the contribution which could be made by climatology. Lively exchanges followed in which several speakers commented favourably on the clarity of the official forecasts, and urged that they never be allowed to lapse into vagueness. Dr. Sutcliffe, in thanking the speakers, said that besides the unit engaged in producing the official long-range forecasts another strongly staffed unit had been formed to explore by more mathematical and theoretical methods the thermodynamic and other processes affecting the slower atmospheric changes.

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A NOTABLE CASE OF DUST IN SUSPENSION OVER CYPRUS

By J. C. GORDON AND R. MURRAY

Introduction.—The thick dust which affected Cyprus for some 12 hours of the night of 18 to 19 December 1962 was of outstanding interest to the professional forecaster in Cyprus as well as to the man in the street. No one could remember a previous occasion with such a prolonged spell of thick dust in suspension in the lower atmosphere. Most professional forecasters would perhaps have been less surprised if the widespread dust had occurred in the late winter or spring, when Saharan depressions have their greatest frequency, rather than in December.

The air circulations leading up to and associated with the widespread dust of this occasion are discussed in this note, as well as some statistics of other occurrences of dust in suspension over Cyprus. As regards the case of dust on 18 to 19 December 1962, no very surprising or inexplicable features come to light, once the synoptic developments were set in train. Indeed the 'reasonableness' of both the synoptic developments and the occurrence of extensive dust in association with the synoptic situation is itself noteworthy. Why similar occurrences are not more frequent is another question to which a satisfactory answer is not given.

General synoptic situation.—The birth-place of the depressions with which the dust over Cyprus was associated was the western Sahara. In this region, some hundreds of miles south of the Atlas Mountains, several days beforehand there were already symptoms of cyclonic development which typically occur whenever cold upper troughs extend southwards over Algeria. The major cold outbreak over the British Isles on 12 December 1962 spread south-south-east to Algeria on 13 and 14 December. During the next day or two the relaxing upper trough moved eastwards over the Mediterranean leaving a cut-off depression in low latitudes near southern Algeria. Subsequently this cut-off low and the associated surface features moved north-eastwards roughly as indicated by the track of the 700 mb low, shown in Figure 1. In the meantime the upper trough, which had been moving eastwards and relaxing, was re-established over Europe and the central Mediterranean as the result of another cold outbreak spreading southwards over Europe.

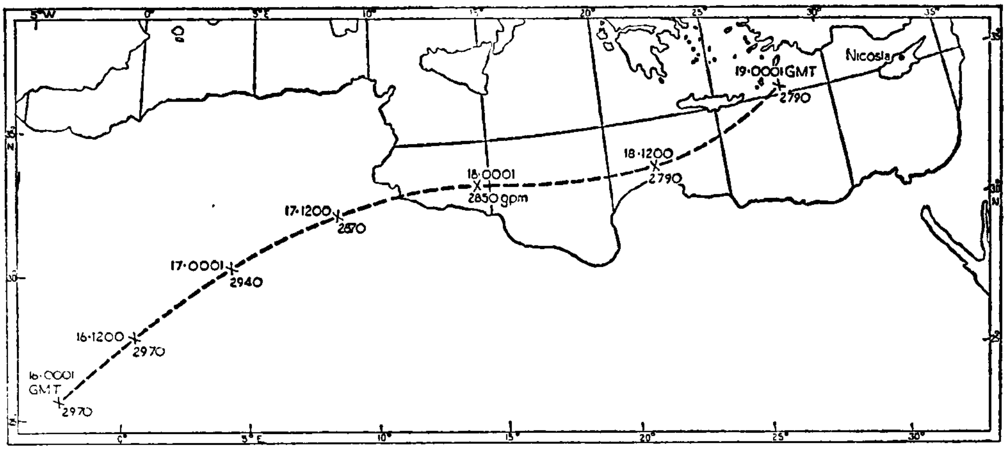


FIGURE 1—TRACK OF LOW AT 700 MB

Position given at 12-hourly intervals from 0001 GMT, 16 December 1962 to 0001 GMT, 19 December 1962. Contour heights at centre in geopotential metres.

The individual synoptic features of relevance were quite firmly in evidence on 17 December 1962. Figure 2 shows the surface chart and 1000–500 mb thickness lines for midday on 17 December 1962. The three frontal systems (A, B and C) had already a fairly long history, and they were maintained on subsequent charts even though some of the fronts, particularly the B system, became very weak and ill-defined. Lows LA and LB which were ahead of the thermal trough on 17 December (Figure 2), were favourably located for development and north-eastwards movement. During the next 24 hours rapid

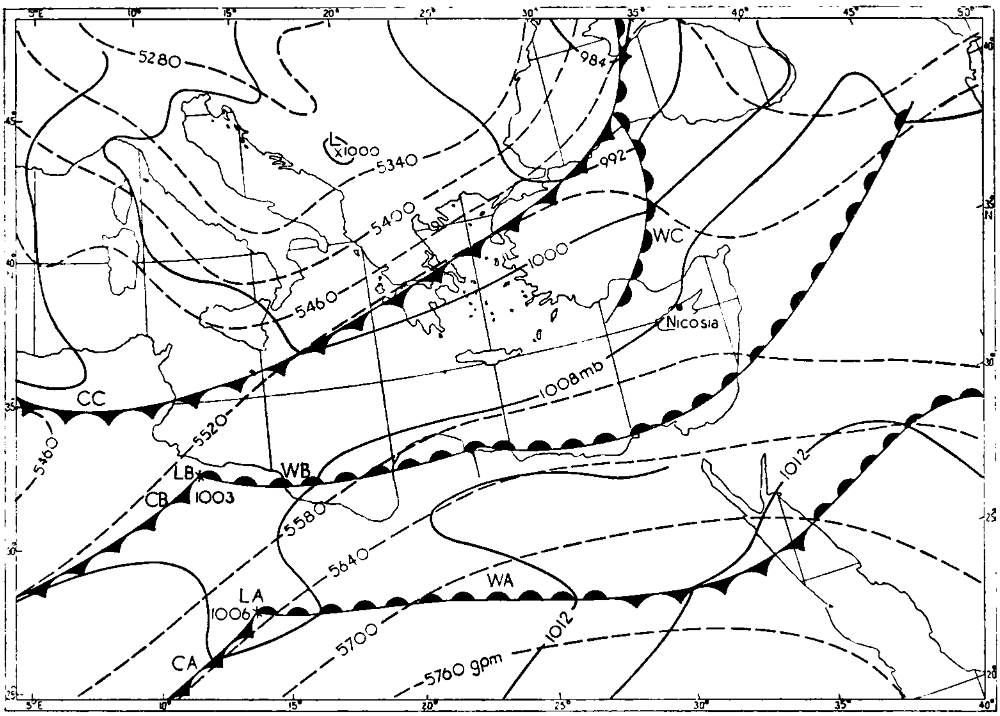


FIGURE 2—SURFACE CHART AND 1000–500 MB THICKNESS LINES FOR 1200 GMT, 17 DECEMBER 1962

——— Isobars, - - - thickness lines.

deepening and movement of LA and LB did in fact occur in association with characteristic distortion of the thickness pattern. At midday on 18 December 1962 (see Figure 3) a vigorous depression was near Crete (actually two centres LB_1 and LB_2 with lowest pressure 983 mb), whilst wave LA was some 70 miles north-west of Alexandria and significant front WA, which had moved quickly

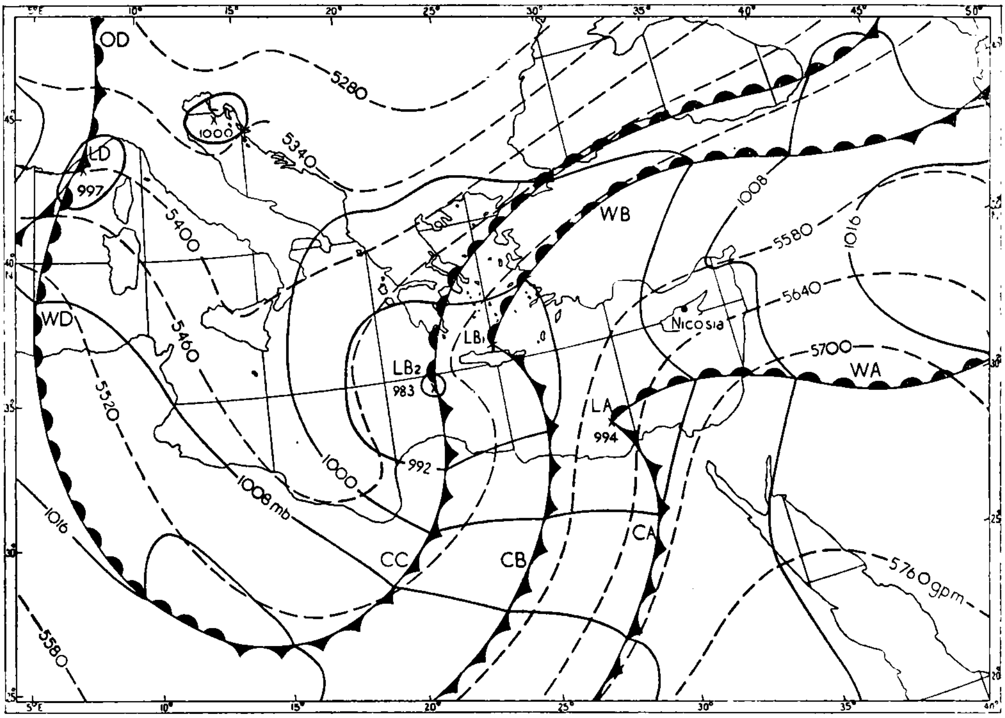


FIGURE 3—SURFACE CHART AND 1000–500 MB THICKNESS LINES FOR 1200 GMT, 18 DECEMBER 1962

——— Isobars, – – – thickness lines.

northwards, was midway between Cyprus and the Egyptian coast. Subsequently the B system moved over Turkey and the mobile wave LA travelled rapidly north-eastwards off the west coast of Cyprus. Front WA moved quickly northwards across Cyprus during the evening of 18 December, followed by dusty air which did not clear significantly until cold front CC swept eastwards across the island during the morning of 19 December. Figure 4 shows the synoptic chart at 1200 GMT, 19 December 1962, and Figure 5 gives the tracks of the main fronts of significance (i.e. WA and CC) at 6-hourly intervals from 1200 GMT, 18 December 1962 to 1200 GMT, 19 December 1962.

Arrival of the dust.—Early on 18 December duststorms were reported at a few places over Cyrenaica. By midday (Figure 3) surface winds had strengthened over an extensive area from Cyrenaica to Egypt, with gale force locally, and widespread duststorms were observed from the African coast to some 300 miles inland. For example, duststorms were reported at 1200 GMT on 18 December at stations El Adem (62063), Gialo (62161), Alexandria (62318), Port Said (62333), Cairo (62366), Minya (62387) and Manqabad (62393). At this time visibility was very good in Cyprus, but pressure was falling sharply and the surface wind was freshening from the south-east in advance of warm front WA (see Figure 3).

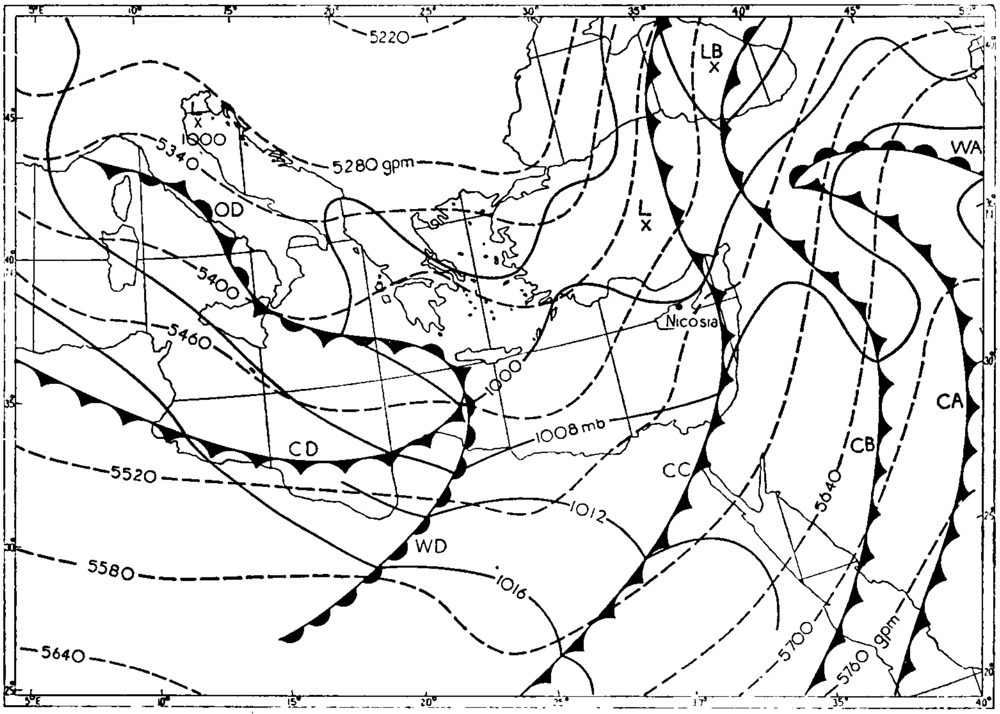


FIGURE 4—SURFACE CHART AND 1000–500 MB THICKNESS LINES FOR 1200 GMT, 19 DECEMBER 1962

——— Isobars, - - - thickness lines.

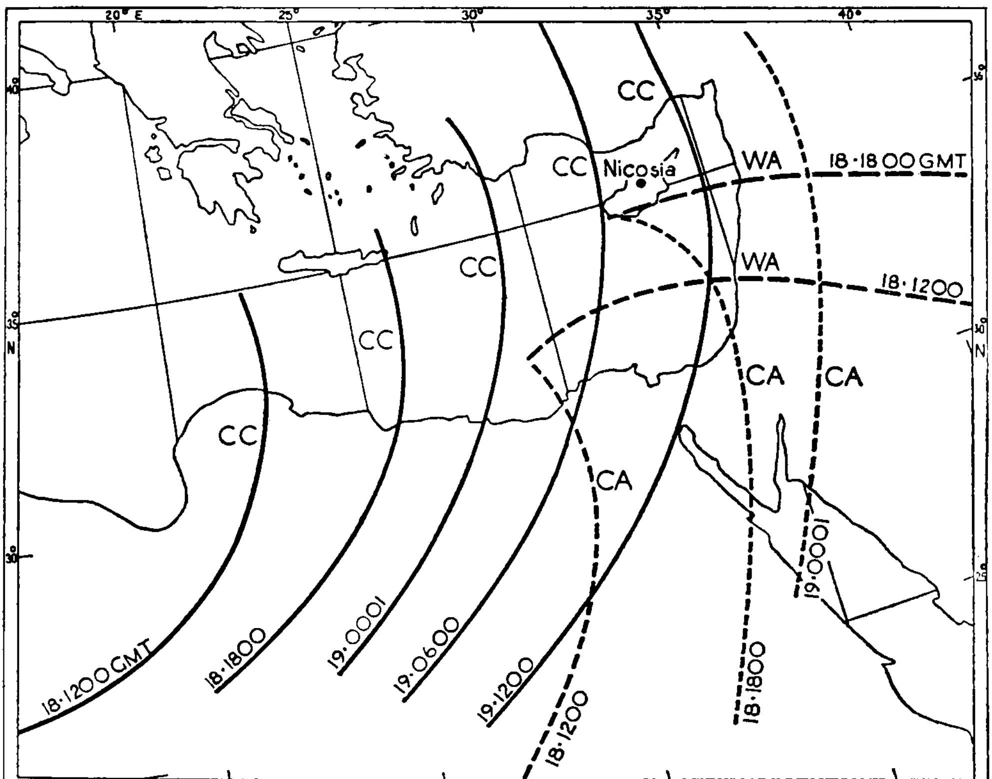


FIGURE 5—SUCCESSIVE POSITIONS OF FRONTS WA, CA AND CC

The date and time (GMT) are shown against the positions of each front.

At Akrotiri on the south coast of Cyprus the passage of front WA about 1827 GMT was marked by a wind veer to 200 degrees 20 knots, a fall in humidity from 75 to 50 per cent, the occurrence of the maximum temperature of the day of 22.2°C (at $3\frac{1}{2}$ hours after sunset) and a drop in visibility to 4 miles. The duty forecaster at Meteorological Office, Akrotiri, reported that "The air was filled with fine dust about the colour and size of face powder. By 1855 GMT the visibility was down to 2000 yards. The cloud structure before the front consisted of broken layers of Sc and Ac but after 1830 GMT the sky was virtually obscured." A further wind veer to 230 degrees 25 knots, with gusts to 34 knots about 1855 GMT was associated with the weak cold front CA.

At Nicosia in the central plain of Cyprus the dusty air was clearly brought in with the passage of the frontal trough about 1945 GMT. About this time the wind veered from 120 degrees 10 knots to 220 degrees 28 knots, with gusts to 38 knots, and visibility dropped from 10 miles to 770 yards. At Nicosia the main wind change occurred during a period of a few minutes, indicating that fronts WA and CA were occluded.

The dusty air which arrived at Nicosia at 1945 GMT on 18 December 1962 was tracked back in time, using quasi-geostrophic trajectories at 3000 feet and 850 mb. At the lower level the surface synoptic charts and 3000-foot wind observations were employed in tracking the air; at the upper level the 850 mb charts and the 850 mb winds were used. It should be noted that the Nicosia upper air sounding at 0001 GMT, 19 December 1962 (see Figure 6) showed a pronounced inversion at 750 mb: below this inversion it is evident that the dusty air was thoroughly mixed in the strong winds. Incidentally, at the same time the sounding at Helwan (near Cairo) gave the base of the stable layer at 870 mb.

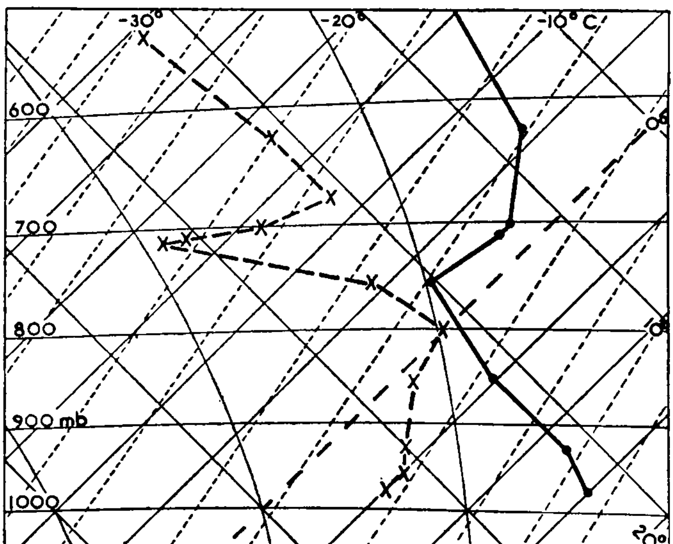


FIGURE 6—TEPHIGRAM FOR NICOSIA FOR 0001 GMT, 19 DECEMBER 1962

——— Dry-bulb temperatures, – – – dew-point temperatures.

Figure 7 gives the track of the air at the two levels. These tracks show clearly that (*a*) the air set out from Egypt where simultaneously duststorms were reported widely, and (*b*) the 'transit' time over the sea from the Egyptian coast to Nicosia was only about 9 hours. Furthermore, it is significant that there were no reports of rain along the track of the dusty air. Thus the air which reached Nicosia at 1945 GMT on 18 December 1962 first traversed a part of Egypt where there was a plentiful supply of dust raised by the strong turbulent winds; then the dusty air moved across the sea to Cyprus with rather little fallout of dust owing to the rapidity of travel and the lack of precipitation.

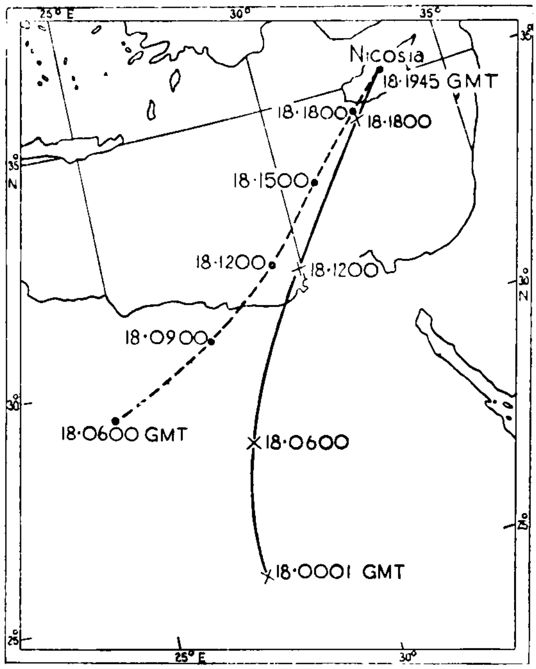


FIGURE 7—TRAJECTORIES OF AIR REACHING NICOSIA AT 1945 GMT, 18 DECEMBER 1962

– – – Trajectory at 3000 feet, ——— trajectory at 850 mb.

The dusty interlude over Cyprus.—At Akrotiri, which was the first place affected by the dust, strong south-westerly winds persisted throughout the night, with a maximum gust of 41 knots, and visibility remained very poor, mostly between 1000 and 2000 yards. Visibility decreased to 300 yards about dawn on 19 December 1962 when intermittent slight rain fell. During the night after about 2300 GMT on 18 December there were outbreaks of slight rain (1.2 mm in all) which "fell as drops of thin mud but did not improve the visibility." In fact the visibility at Akrotiri and at other stations in Cyprus decreased even further when muddy rain fell.

Following the arrival of the dusty air at Nicosia the visibility remained generally poor throughout the night for some 12 hours, with a minimum visibility of 660 yards about 2100 GMT on 18 December.

The dust was reported from other parts of the island during the night. For example the visibility dropped to 770 yards in association with rain at Paphos immediately in advance of front CC. The minimum visibility was 1400 yards at Morphou Bay near the north-west coast and it was 1700 yards at Ayios Nicolaos near Famagusta on the east coast. Many motorists noted, in the morning, that their cars were spattered with a thin sand-coloured mud. Actually there was little or no rain for the greater part of the dusty interlude, but some rain fell in most places, almost exclusively with the approach of front CC on the morning of 19 December. Examples of rainfall amounts for the 12-hour period ending at 0600 GMT on 19 December are as follows: trace at Nicosia, 1.2 mm at Akrotiri, 3.7 mm at Paphos, 0.4 mm at Morphou Bay and 5.6 mm at Ayios Nicolaos.

The air at low levels over Cyprus during the night and early morning had undoubtedly been advected from Egypt or Cyrenaica in the strong south-west winds. For instance the dusty air over Nicosia at 0001 GMT 19 December almost certainly left the Egyptian coast between Salloum and El Alamein around 1200 GMT 18 December, at which time duststorms were widely reported over Cyrenaica and Egypt from El Adem to Port Said. Figure 8, which shows the approximate trajectories of air at 3000 feet and 850 mb, is relevant.

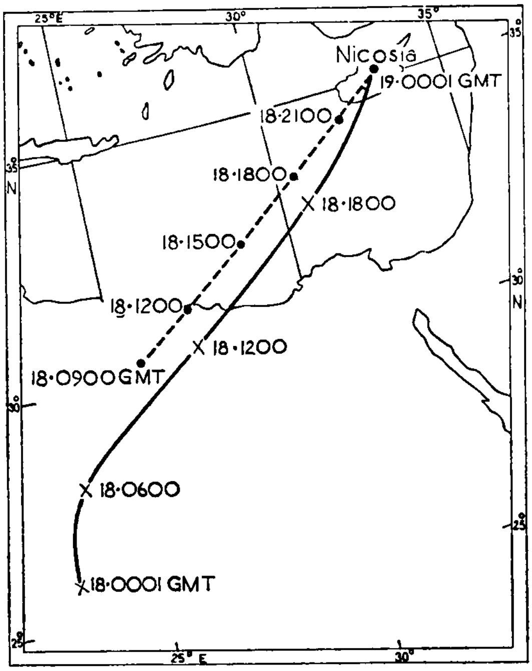


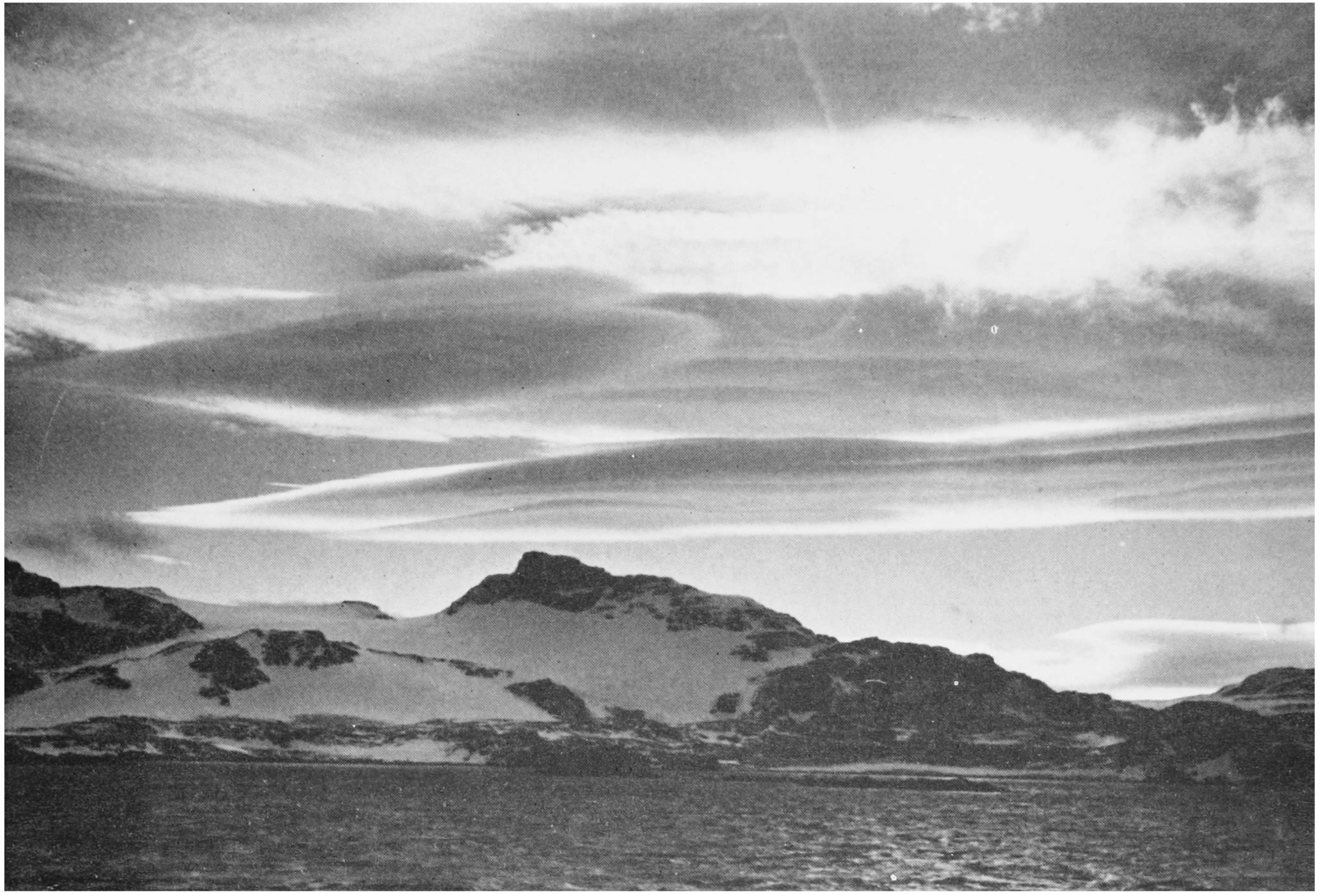
FIGURE 8—TRAJECTORIES OF AIR REACHING NICOSIA AT 0001 GMT, 19 DECEMBER 1962

– – – Trajectory at 3000 feet, ——— trajectory at 850 mb.

It is noteworthy that over the source of the dust in Egypt and eastern Cyrenaica the surface air was very dry on 18 and 19 December; and the weak cold fronts which swept eastwards across this region gave virtually no rain east of about El Adem. There was probably little or no rain along the track of the dusty air until near Cyprus and even then mainly with the approach of front CC rather late in the period of roughly 12 hours of dust over Cyprus. Thus there was evidently insignificant washing out of dust by rain in the rather short transit time from the source of extensive duststorms.

Clearance of the dust.—The main clearance of the dusty air over Cyprus took place with the eastwards passage of cold front CC (see Figure 5). For instance, at Nicosia the frontal trough passed by at 0745 GMT on 19 December with an almost immediate improvement of visibility to 4 miles; whereas at Akrotiri, where the frontal passage was a little earlier, the visibility improved to 3¾ miles at 0710 GMT and to 10 miles by 0800 GMT. Westwards of cold front CC the visibility over Cyprus was generally good or very good on 19 December.

To face p. 112



Photograph by P. A. Richards

PLATE I—LENTICULAR LEE-WAVE CLOUD OVER SIGNY ISLAND ON 30 MARCH 1958
The photograph was taken looking west from the base hut shown in Figure 1 on page 118.

Photograph by A. Stemmler

PLATE II—DAMAGE RESULTING FROM A TORNADO AT LABUAN ON 25 JULY 1963

A wooden hut was moved bodily 10–15 yards and disintegrated. The remnants of a coconut palm can be seen at the corner of the concrete base of the hut, (see page 120).

Photograph by A. Stemmler

PLATE III—DAMAGE RESULTING FROM A TORNADO AT LABUAN ON 25 JULY 1963

When an iron-roofed long house was completely wrecked, some of the corrugated iron was twisted and screwed up like waste paper, (see page 120).

To face p. 113

Crown copyright

PLATE IV—GIFT FROM THE GHANA METEOROLOGICAL SERVICES

See page 126.

The air which reached Nicosia at low levels about 0745 GMT in the rear of front CC was tracked back. Figure 9 shows the approximate trajectories. The air at 3000 feet appears to have been near Athens at 1200 GMT 18 December, near south Crete at 1800 GMT 18 December and then to have travelled eastwards to Cyprus. It was not possible to track the air beyond the Athens area

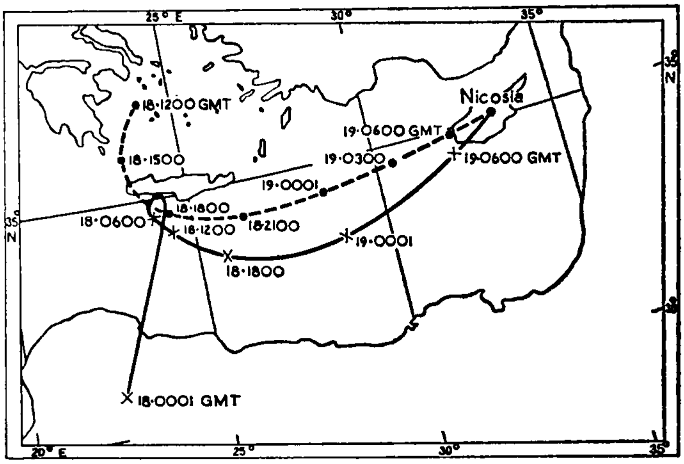


FIGURE 9—TRAJECTORIES OF AIR REACHING NICOSIA AT 0745 GMT, 19 DECEMBER 1962

– – – Trajectory at 3000 feet, ——— trajectory at 850 mb.

with any confidence. However it is probable that the air which reached Nicosia at 850 mb at 0745 GMT 19 December left Cyrenaica soon after 0001 GMT 18 December. This air almost certainly moved northwards from Cyrenaica to near Crete, then, after some hours of partial stagnation, eastwards to Cyprus. Even if the air at 850 mb originated over Africa, it must have travelled for at least 24 hours over the sea along a track where considerable precipitation fell and where the lower troposphere became increasingly unstable. Thus there was ample time for the concentration of dust originally in suspension to be significantly diminished by two processes, namely, (*a*) washing out by falling rain and (*b*) dispersion upwards in the fairly unstable air.

Other occasions of dust over Cyprus.—As a basis for comparison with the dust of 18–19 December 1962 the records for Nicosia for the years 1953–62 inclusive were scrutinized for other occasions of dust in suspension.

Surprisingly, there were only 3 occasions of significant dust haze at Nicosia during the period 1953–1957 and on none of these was the visibility seriously reduced. Synoptic charts were not available at Nicosia for this period.

During the subsequent 5-year period there were 23 instances of dust haze, excluding the case on 18–19 December 1962. While the majority of the extreme deteriorations in visibility due to dust lay in the 2–5 miles range, there were a number of instances when visibilities were lower than this and on one occasion the minimum visibility recorded was 1500 yards. This should be compared with a minimum visibility of 660 yards at Nicosia (and 300 yards in dust and rain at Akrotiri) in the case of 18–19 December 1962. Incidentally rain was reported on only 3 occasions during the dusty periods and the minimum visibility in rain was 2000 yards (this does not include the occasion of 18–19 December 1962). The average duration of the dust was about 11 hours though the actual periods varied from about 1 hour to 41 hours. It is noteworthy that prior to all the instances of dust haze the surface wind at Nicosia was persistently easterly or south-easterly. However, the actual onset of the dust and the subsequent occurrence of the dust were associated with surface winds at Nicosia from a variety of directions; indeed on about one-third of occasions the surface wind was from a westerly point. On the other hand the clearance of the dust at Nicosia was generally associated with surface winds between south-west and north-west.

The 24 instances of dust occurred from November to May, with a maximum frequency in March; none occurred from June to October.

These cases were further examined to find the sources and synoptic situations associated with the dust over Cyprus. On all but two of the times the source of the dust was North Africa. On the other two occasions the dust originated over the Arabian peninsula and Iraq.

Of the 24 cases of dust only 16 were really distinct. For example dust was reported for varying periods on 13, 14, 16, 17, 18 and 19 January 1960 (the visibility on 14 January was actually reduced to 1500 yards for 8 hours), thus giving 6 instances. However, the synoptic pattern for the whole of the period from 13 to 19 January 1962 consisted of a series of cold fronts moving from west to east across North Africa and the central and eastern Mediterranean in association with a family of depressions moving east across central Italy and then north-east to the north of the Black Sea. The final clearance of the dust was brought about by a rise of pressure over Algeria and Tripolitania, resulting in the maintenance of north-westerly surface winds over Cyprus.

Examination of the dusty periods of 1958–62 suggests that there are three typical synoptic situations which give rise to dust over Cyprus. These are as follows:

(i) An intense depression is situated over the central Mediterranean with associated cold fronts moving eastwards over North Africa.

Widespread rising sand can occur both ahead of and behind the fronts. The widespread dust in suspension normally arrives over Cyprus in south or south-east winds and clears with the passage of the final cold front, usually in association with the build-up of an anticyclone over Algeria, Libya and the central Mediterranean and the movement north-eastwards of the main low centres.

(ii) Depressions which move from North Africa.

There are several variations. Depressions may move eastwards from the semi-permanent low pressure area over central Algeria following a fresh burst of cold air from the north. Depressions may originate over Libya and move eastwards or secondary depressions may form in the circulation of an intense depression over the central Mediterranean. For these lows to bring dust over Cyprus it seems that they should have a fairly intense circulation and the tracks of their movement should lie within the belt shown in Figure 10. There were no cases of dust reported at Nicosia with centres passing south of the belt shown in the figure. Furthermore, the dust frequently arrives over Cyprus in surface winds between south-west and north-west. The average duration of the dust is 5 or 6 hours but on one occasion it persisted for 16 hours.

(iii) A stationary or slow-moving depression is situated over the extreme south-east Mediterranean or over Saudi Arabia with a strong circulation on its eastern side.

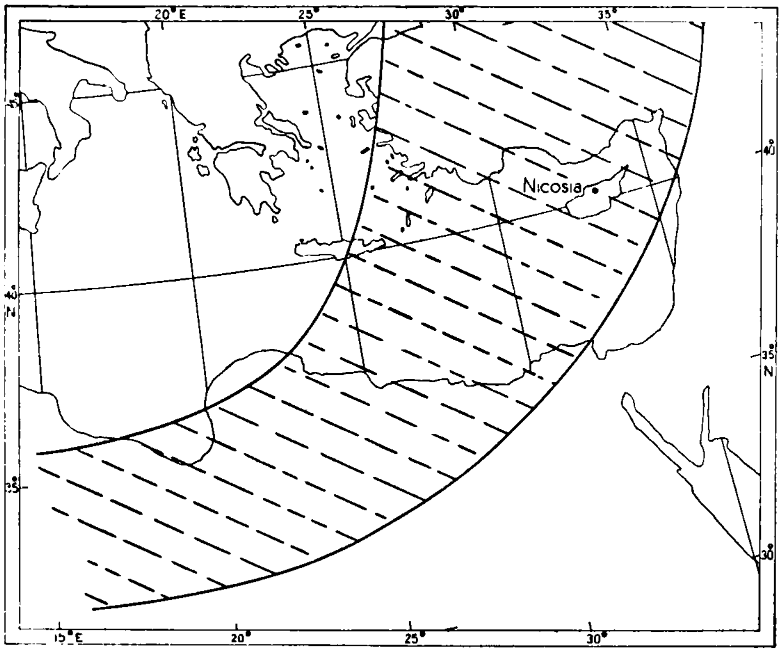


FIGURE 10—AREA ENCLOSING TRACKS OF AFRICA LOWS WHICH MAY BRING DUST TO CYPRUS

Errata: all latitudes are 5° too large

In this case dust may reach Cyprus from Saudi Arabia, Iraq or Syria and it may persist for quite considerable periods. The clearance is again associated with the build-up of pressure over the central and eastern Mediterranean.

Within the limitations of the data examined, it appears that types (i) and (ii) are about equally frequent and type (iii) is rather uncommon.

The existence of synoptic situations similar to those indicated as types (i), (ii) and (iii) is not of course a sufficient reason for the occurrence of widespread dust over Cyprus. There should additionally be a fairly low inversion (at about 850–700 mb) to restrict the vertical dispersion of the sand or dust, marked instability below the inversion, a minimum of precipitation so that the dust is not washed out and a minimum trajectory (in time) of the dust-bearing air between the source region and Cyprus. These additional factors were all present to a marked extent in the outstanding case of 18–19 December 1962.

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INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS THIRTEENTH GENERAL ASSEMBLY, BERKELEY, CALIFORNIA, 1963

By E. KNIGHTING

The Thirteenth General Assembly of the International Union of Geodesy and Geophysics (UGGI) was held at the University of California, Berkeley from 19–31 August 1963. All seven of the International Associations held their own meetings concurrently and there were a number of joint symposia such as those on Evaporation (International Associations of Meteorology and Atmospheric Physics, IAMAP, and of Scientific Hydrology, IASH,) and Ocean–Atmosphere Interaction (Association of Physical Oceanography, IAPO, and IAMAP).

The papers read in IAMAP were mainly divided into symposia on subjects such as meteorology of the upper atmosphere, interaction between ocean and atmosphere (with IAPO), radio meteorology, atmospheric and space electricity (with the Association of Geomagnetism and Aeronomy, IAGA,*), atmospheric turbulence, evaporation, with other shorter symposia. Several of these symposia overlapped so that no one could attend all the meetings, but the lecture halls were sufficiently close to make it possible to hear papers first from one and then another session. The total number of papers almost reached two hundred, at least a fifty per cent increase on the number read at Helsinki[1] three years ago; over forty papers were read in the symposia on meteorology of the upper atmosphere. Dynamical meteorology and the general circulation were deliberately excluded because the International Commission on Dynamical Meteorology was to hold a special symposium on dynamical meteorology at Boulder immediately after the UGGI General Assembly.

Interest in the upper atmosphere has been steadily increasing over the last decade because the instruments for making observations have multiplied and revealed the intrinsic interest and importance of the region, and also because there is the practical problem of determining where the products of nuclear devices will be found at later times. Observations cover a wide variety of atmospheric substances such as water vapour, ozone, atomic oxygen and nuclear tracers as well as the more conventional winds and temperatures and in some cases information exists to levels above 100 km; further observational material is accumulating rapidly and is so diversified that workers in the field must have a detailed knowledge of the specialized physics and chemistry of this region as well as being dynamical meteorologists. A number of papers dealt with the observational material and its qualitative explanation in terms of upper atmospheric circulations, others dealt with the energy exchange processes in the upper atmosphere and there was occasional recourse to the electronic computer to carry out computations of possible circulations. The views held by the various speakers are still diverse and it is fair to say that as yet there is no agreed interpretation of many aspects of the observational evidence; nevertheless it is clear that progress has been rapid in the last few years and a coherent picture of the upper atmosphere will eventually emerge. A few papers dealt directly or indirectly with ozone measurements, particularly valuable because of all the upper atmospheric constituents ozone is perhaps the best understood and most widely observed and a wealth of data from the International Geophysical Year remains to be dealt with. Among other interesting papers (which included some on radiation in the upper atmosphere) were a few offering further data and tentative hypotheses about the 26-month oscillation in the tropical stratosphere, but the mystery remains.

The interaction between the oceans and the atmosphere must be as important as any other factor in determining the atmospheric circulations which exist and in attempting to make predictions over periods longer than a few days; it is equally important to the oceanographer and perhaps the stress in the joint symposia with IAPO was in his direction. It seems that at present the oceanographer is better able to make use of observed winds to explain the oceanic circulations than is the meteorologist to use oceanographic observations to explain atmospheric circulations. Perhaps more joint research is required

*The remaining three associations are the International Associations of Geodesy (IAG), of Seismology and Physics of the Earth's Interior (IASPEI) and of Volcanology (IAV).

before meteorologists can get the help that they need to remove the gross assumptions that are commonly made at sea level in their atmospheric models. On the other hand radio and radar experts seem to have more to offer to meteorology than they receive although many obscurities still remain and it appears that the theory of superrefraction still has to be agreed. The shorter symposia all had papers of interest, e.g. the observational material obtained from satellites was well discussed although its full impact on meteorology is yet to be felt.

The very large number of papers presented suggests that the amount of research work in meteorology is greater than ever before, especially if it is remembered that only certain facets of the research were presented at Berkeley, and it is certainly true that the volume of published papers is increasing as is the number of meteorological reports which do not appear in the established journals. With so much research going on it is almost inevitable that symposia as presently organized are made up of papers read by specialists in a rather narrow field and hence lack cohesion, however the organizers may try to achieve it. There is much to be said for IAMAP meetings being devoted to a series of carefully prepared review papers in the various branches of the subject, leaving the specialists to read their papers at the meetings organized by the International Commissions. At least, each symposium should commence with an adequate review to set the stage for the subsequent papers.

The setting of the meetings could scarcely be bettered, for the Berkeley campus is a very fine one with a more than adequate supply of good lecture theatres. The reception committee had done its work well and provided all the facilities that were needed for transport and accommodation and in the glorious weather we were all made very comfortable indeed.

REFERENCE

1. KNIGHTING, E.; International Union of Geodesy and Geophysics Twelfth General Assembly, Helsinki, 1960. *Met. Mag., London*, **89**, 1960, p. 301.

551.558.21:551.576.11

LENTICULAR LEE-WAVE CLOUD AT SIGNY ISLAND

By P. A. RICHARDS

The following notes were compiled from observations made at Signy Island (60°43′S, 45°36′W) in the South Orkneys during 1958 and 1959.

The Pomona Plateau (general height 1500–1700 feet) situated at the western end of Coronation Island (Figure 1) appears to form standing waves under certain conditions giving rise to a series of lenticular lee-wave clouds. These form at right angles to the flow of the upper winds and have a base at about 6000 feet. The waves set up appear to have greatest amplitude at the position of the second wave, as on several occasions this was the only position where cloud formed. The wavelength between each cloud was 3½ miles, the clouds being 5–8 miles in length (Figure 1 and Plate I). The cloud formed only in the summer months on days when the surface temperature was above 0°C.

G. A. Corby* gives three conditions suitable for the formation of waves:

(i) Marked stable layer, approaching the isothermal, or an inversion, through some layer below 10,000 feet;

(ii) Wind direction fairly constant with height;

(iii) Wind speed increasing with height.

*CORBY, G. A.; Air flow over mountains. *Met. Rep., London*, No. 18, 1957, p. 36.

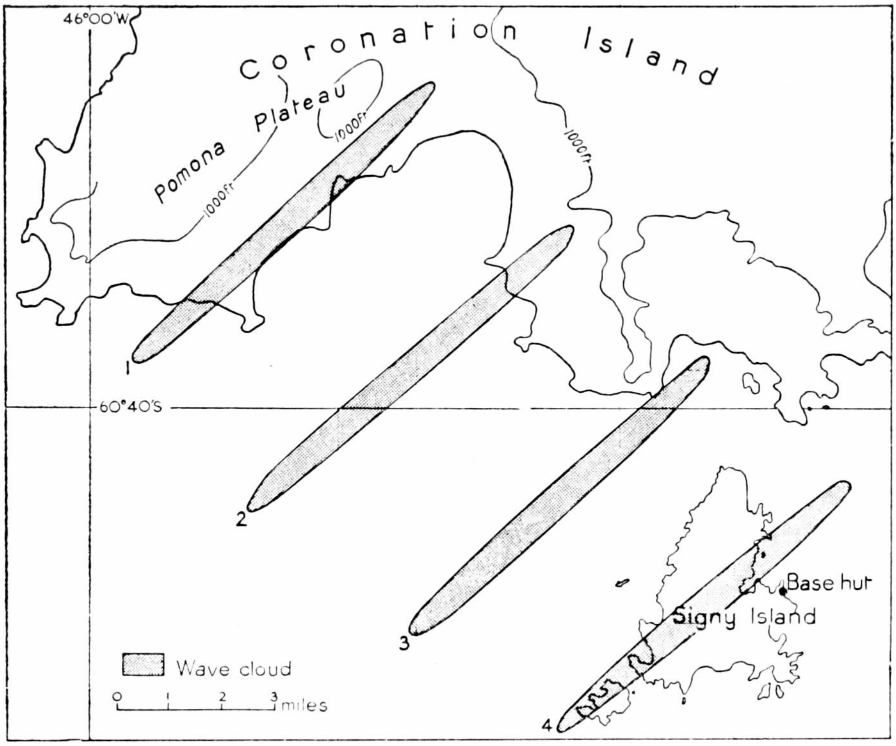

FIGURE 1—MAP OF THE AREA AND POSITIONS OF FOUR OF THE LEE-WAVE CLOUDS

Wave clouds are numbered 1 to 4.

Owing to lack of information nothing is known of the upper air temperatures when cloud formed, but on all occasions the area was in a ridge of high pressure with slight barometric tendencies indicating stable conditions.

On the eight occasions when upper winds were obtained when wave clouds were present, the wind direction between the surface and 8000 feet never varied more than a few degrees (270°–310°) (see Table I). It will be seen that the strongest upper winds were recorded on 10 October 1958, the day on which the greatest number of wave clouds (6) was observed.

TABLE I—UPPER WINDS RECORDED ON OCCASIONS WHEN WAVE CLOUDS WERE PRESENT

Date	Time GMT	1000	2000	3000	4000	5000	6000	7000	8000	Position number of wave cloud (see Figure 1)
		Height in feet — Direction and speed of wind, *degrees/knots*								
1958										
30 Mar.	1715	290/31	300/27	320/32	290/21	280/13	290/20	290/35	280/35	1,2,3
4 Apr.	1700	290/11	300/15	290/23	280/22					1,2,3,4 at 8000 ft: 3
6 Apr.	1700	300/12	280/20	280/24	270/26	290/28	280/32	280/31	290/44	2
9 Apr.	1500	300/25	290/39	290/40	290/35	290/30	280/36	280/46	290/52	2
25 Apr.	1700	290/14	280/27	280/25	270/16	280/21	290/24	280/28	270/24	2,3
10 Oct.	1200	300/19	290/21	300/32	300/48	290/58	280/38	290/37		1,2,3,4,5,6
25 Nov.	1700	300/19	310/18	290/17	290/25	280/26	280/25	280/21	280/29	2,3
1959										
29 Mar.	1400	310/15	300/18	270/18	270/14	290/29	290/43	290/40	280/23	2 (occasionally sign of cloud at 1)

Acknowledgement.—The author was working for the British Antarctic Survey at the time of these observations and wishes to thank it for agreeing to publication of the article.

551.515.33

TORNADO AT LABUAN—25 JULY 1963

By A. STEMMLER and P. M. BATE

The following report of a tornado may be of interest. It occurred about 1745 local time on 25 July 1963 over Labuan Island off the coast of North Borneo, approximately 5 degrees north of the equator. Figure 1 shows the track of the tornado near the airfield, and where the main damage occurred. The tornado was observed to have a counter-clockwise rotation and a path width of about

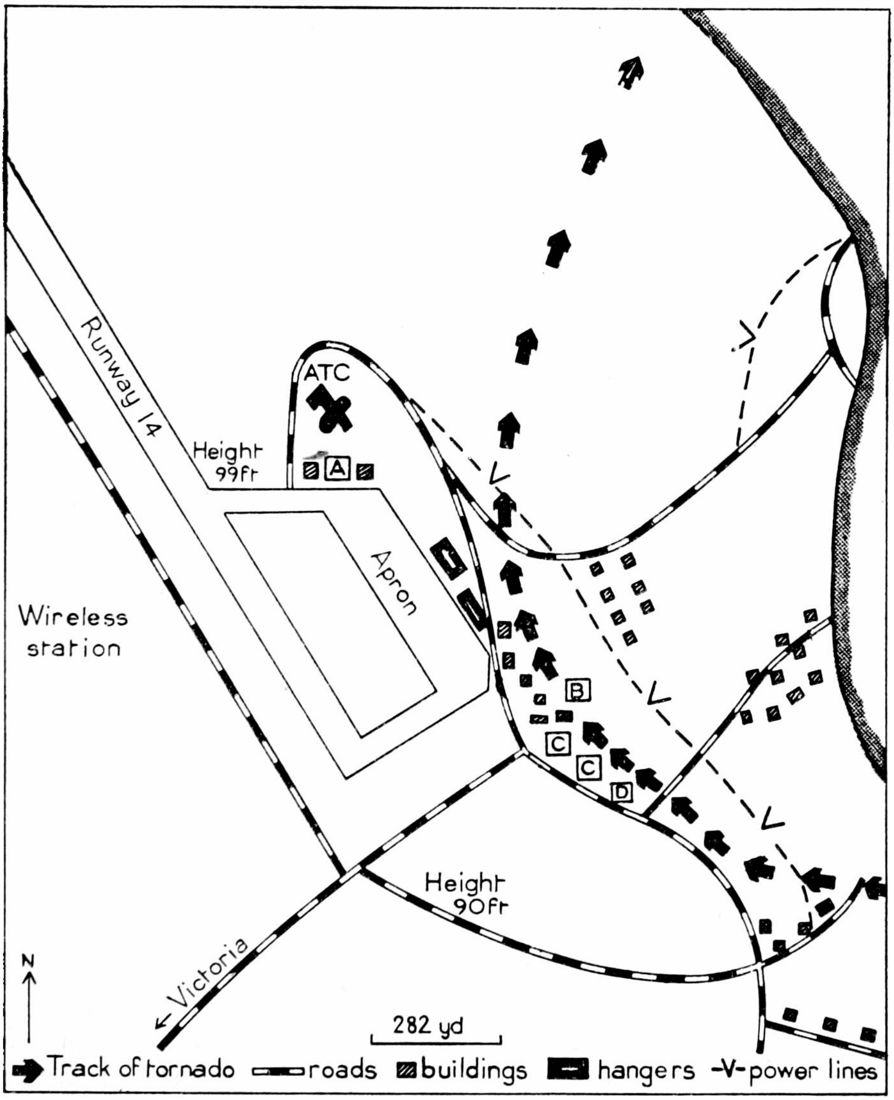

FIGURE 1—TRACK OF TORNADO ON LABUAN ISLAND, 25 JULY 1963

A—Pressure-tube anemograph;
B—Demolished hut and two radio masts;
C—Deroofed corrugated-iron long houses; D—Uprooted tree.

10 to 20 yards. It was seen to move initially to the north-west with a speed of about 20 to 25 knots, and then it recurved to the north-east. During its passage pieces of corrugated iron (6 feet by 4 feet) were whirled around at about 800 feet above the eastern edge of the airfield and carried half a mile before being deposited on the ground, whilst two large corrugated-iron 'long houses' were completely deroofed and the iron wrapped round the power lines nearby, cutting off the electricity supply to the Labuan Hotel, the airfield and nearby houses. In addition a large tree near the site of the long houses was uprooted, a Valetta aircraft parked on the apron was revolved through 180 degrees without damage, one small wooden hut was moved about 100 yards and demolished and two small wooden houses were almost demolished. The gutters of most stone-built houses in the area were ripped off and two large wireless aerials were carried away—half of one was never recovered. Some of the damage is shown in Plates II and III.

The weather leading up to the tornado was as follows. During the early afternoon of the 25th, the usual large cumulonimbus cloud formed near Mount Kinabalu (see Figure 2). A large anvil developed by 1500 local time

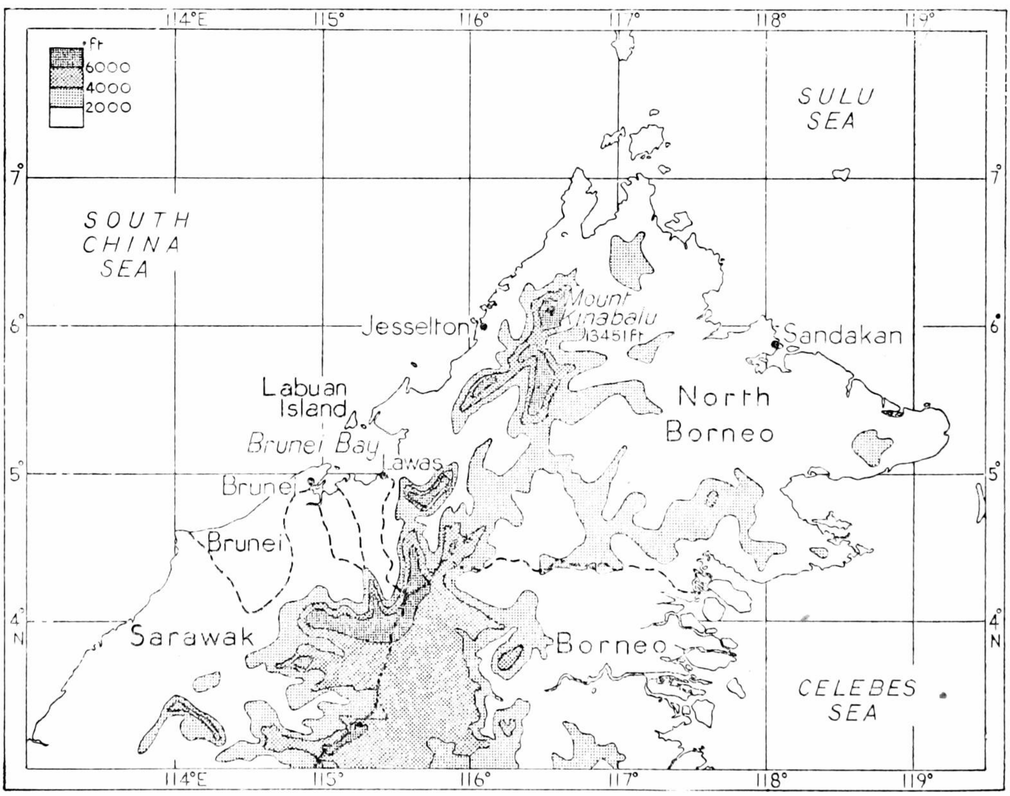

FIGURE 2—MAP OF THE AREA

and a cirrus canopy streamed downwind with the upper-level winds in the direction of Labuan Island. The main cloud appeared to be propagating south-south-westwards towards Lawas and Brunei and some high ground was covered in cloud. Otherwise the predominating cloud was cumulus mediocris until about 1600 local time, when another cumulonimbus developed over Brunei to the south-west of Labuan and amalgamated with the one formed earlier.

By 1700 local time a solid wall of cumulonimbus cloud had developed to the south of Labuan with almost 8/8 of anvil cirrus and by 1730 the now solid mass of dark cloud was only a few miles to the south of the airfield. Even at this time there was no real evidence of any particularly unusual phenomenon approaching, nor was a funnel cloud observed, but at 1745 the westerly sea breeze of 11 to 14 knots changed rapidly to 150 degrees and a sustained squall of 36 knots was registered on the anemograph. It is thought that this reading was a serious underestimation of the true wind because the anemometer was obstructed by trees. The Air Traffic Controller and the local meteorological observer estimated that the maximum gusts near the air traffic control building exceeded 60 knots. There was some suggestion that a line-squall moved from the south-west, because at 1750 local time the hygrograph showed a marked rise in humidity from 76 to 92 per cent whilst the thermograph showed a fall from 86 to 79°F. Little or no rain fell until 1800 local time but by 2000 1.4 inches of rain had been recorded with 1 inch falling between 1900 and 2000.

551.593.653:551.594.5

NOCTILUCENT CLOUD AND AURORA

By F. D. BYRNE

It is not often that noctilucent cloud is visible at the same time as an aurora. Paton reports (with photographs) such an observation on 24–25 July 1950[1] at Abernethy, Perthshire, and I was fortunate to see this rare occurrence at Lerwick during the night of 30–31 July 1963.

The noctilucent cloud was first visible at 2245 GMT towards the west-north-west, extending from an elevation of 18° in the north-west to 26° in the west, and covering about 1/16 of the sky. It was silvery white in colour and very clear, with traces of normal cirrus, appearing dark, below it. As the sun descended lower below the horizon the noctilucent cloud lost much of its luminosity, and at midnight was barely discernible, but by then an auroral arc was also visible towards north-north-east, at a maximum elevation of 6°. This arc was faintly red in the north becoming yellow green in the north-east, bright but inactive. At 0030 the auroral arc was red at the base and yellow-green at the top, now with rays of moderate brightness, and the noctilucent cloud was becoming brighter.

Between 0030 and 0130 GMT the noctilucent cloud became brighter, and the aurora apparently weaker as the sunlight increased in the north-north-east sector. The noctilucent cloud was in almost the same position as at 2245, but it had become more patchy and less fibrous than before. By 0215 it had spread or increased to south of west and extended from approximately north-west to west-south-west, still at the same elevation, and still less than 1/8 in amount.

Auroral arcs are usually seen from Lerwick in a direction slightly west of north, but in this direction there may have been too much light for it to be visible, and only the eastern section was sufficiently bright to be seen. The Lerwick magnetograms indicate that the aurora probably began at midnight, reached its maximum around 0045 GMT and decreased slowly afterwards.

The best time for observing noctilucent cloud is when the sun is 6° to 7½° below the horizon. At this time, around 0230 GMT, the amount of cloud appeared to increase until the amount was at least 1/8, and it resembled a mixture of cirrus and cirrocumulus: it was very distinctive and extended from north-west to west-south-west. Thereafter as the sun rose the cloud seemed to lose its texture and the impression of great height, until by 0330 it was no longer distinguishable from ordinary cirrus.

Those of us who have definitely observed noctilucent cloud this summer realize that we have probably seen it previously, and reported it as cirrus type cloud without really knowing what it was. If there is no moon it is not difficult to recognize, because noctilucent cloud appears bright against a darker sky, while lower cloud appears dark against a brighter sky. Our attention was drawn to these clouds by an excellent account of noctilucent cloud in the *Scientific American* by R. K. Soberman.[2]

REFERENCES

1. PATON, J.; Simultaneous occurrence of aurora and luminous night clouds. *Met. Mag., London*, **80**, 1951, p. 145, and Figures facing p. 139.
2. SOBERMAN, R. K.; Noctilucent clouds. *Sci. Amer., New York*, **208**, 1963, p. 50.

REVIEWS

Experimentelle Untersuchungen mit Hilfe von ionisierenden Strahlen und Neutronen zur Bestimmung der witterungsbedingten Wachstumsintensität von Kulturpflanzen am natürlichen Standort, by Kurt Unger. $9\frac{1}{4}$ in. × 6 in., pp. 75, *illus.*, Akademische Verlagsgesellschaft Geest & Portig K. -G., Leipzig, 1963. Price: DM 12.

The relationship between plant development and environment is of great theoretical and practical importance but in spite of much effort our present knowledge is very sketchy. This is largely because the problem has been examined in very general terms; meteorological parameters have been compared with total yields or with the development of the plants to certain specified phenological stages. Now that more sophisticated instruments permit a detailed recording of the micrometeorology of a crop stand, any improvements in the recording of plant growth should lead to a rapid extension of our knowledge of the relation between the two. So far, the only practicable method of estimating the increase in the mass of a plant has been to uproot and to weigh it. The removal of plants from a stand leads to changes in the environment and it is therefore most desirable that the growth be estimated *in situ*.

This publication is largely devoted to a description of instruments which can be used for this purpose. These are based on the principle that the attenuation of β-, γ-, and X-rays can be used as an estimate of the mass of material through which they are transmitted. Two types of apparatus are described; the first is used in estimating the development of individual plants which have a closed head, such as a lettuce or cabbage. This consists of a portable bow-shaped apparatus which is placed over the plant so that the radio-active source is on one side of the plant and the detector on the other. Two methods have been used to estimate the growth rate of plant stands. In one, a circular field was divided into 12 sectors, each containing a crop; at the centre ^{60}Co (a radio-active isotope of cobalt) was used as a source of γ-rays; the transmitted radiation was measured on a scintillation counter which could easily be moved round the edges of the various plots. The second method involved the construction of a bridge over the stand; this moved along rails on each side of the stand, with the source and detector at stand level. The results from these types of measurement are normally expressed in mass per unit area. When these were compared with a system of growth recording depending on the number of internodes (in peas) the correlation coefficient was as high as 0.825 and significant at the 1 per cent level.

Measurements of plant development have now been made for some years at Quedlinburg in Saxony for comparison with the micrometeorological records of temperature, evaporation, global radiation and soil moisture. The last named has been measured by neutron scattering. These measurements will be published in due course, but examples of the relationships which can be derived from them are given in this publication. Briefly it may be stated that the effect on growth of temperature and evaporation may be represented by cubic polynomials, and the effect of soil moisture and radiation by linear regressions. The four elements together can give a reasonable estimate of growth; the multiple correlation coefficient between observed growth and the theoretical growth due to these environmental factors is 0.83 and is significant at the 5 per cent level. Thus 69 per cent of the variation in growth can be accounted for by four environmental factors; the remainder is due presumably to other factors or to experimental error.

This publication is of interest mainly to those concerned with the principles of the instrumentation involved in the detailed estimation of the variations in growth rate during the life of individual plants or stands of plants. Those who are more interested in the results of measurements already made will look forward to their appearance.

W. H. HOGG

The physical geography of the sea and its meteorology, by M. F. Maury. Edited by John Leighly, 9¼ in. × 6 in., pp. xxx + 445, *illus.*, Harvard University Press, Cambridge, Mass. Price: 68*s*.

The modern layout and excellent standard of production of this book make it necessary to emphasize at once that it was originally published more than a century ago and that it is now being republished for its historical interest—its ideas are not all acceptable today. However, it was written with the persuasive enthusiasm of a pioneering personality, and is very readable as an interesting piece of writing from the past, reflecting the interest and methods of an age twenty years before the Challenger Expedition of 1873–76.

The original book is no doubt available in various libraries but it has been chosen for republication as one of the John Harvard Library series which is financed by a permanent trust fund set up by Waldron Phoenix Belknap, Jr. The series is intended to make rare books and documents about the American cultural past more readily available to scholars and the general reader at a reasonable price.

This reissue of Maury's book will appeal to the historian or librarian of science, to all who are interested in American cultural history, and to the meteorologist or oceanographer with time for leisure reading. Such is made clear in an admirable 30-page introduction by the editor, John Leighly, Emeritus Professor of Geography, University of California, Berkeley. In this introduction is an account of the origin of the book, a summary of the reviews made in the years when the book was new, and a modern appraisal which makes the reader aware of the major criticisms of the scientific content of the book.

The following useful background to the book is based on Professor Leighly's introduction. From 1842 to 1861 Matthew Fontaine Maury was superintendent of the United States Navy Depot of Charts and Instruments (later called the Naval Observatory and Hydrographical Office). He arranged to extract observations from log-books of Naval vessels and in 1847 he issued the first of his 'Wind and Current Charts' for use in the navigation of sailing ships. The average time for a voyage from England to Australia was reduced from 124 days to 97 days when these charts were used, and therefore navigators were keen to co-operate when he made arrangements for special charts and forms to be used on board ship for recording observations. Maury played a leading part at an international maritime conference in 1853 at Brussels whereby ship observations were organized on a world wide basis. From this conference arose the official weather services of many countries including the British Meteorological Office under Admiral FitzRoy who had considerable correspondence with Maury. The 'Wind and Current Charts' were augmented by 'Explanations and Sailing Directions,' which also contained various articles written by Maury. The 'Sailing Directions' grew larger with every edition and eventually, for copyright protection, some of the contents were published in 1855 as '*The Physical Geography of the Sea.*' Many editions followed, both in America and elsewhere. The eighth and last American edition of 1861 is used for this republication in 1963. (In the Meteorological Office Library there is a copy of an English edition of 1855—'second edition enlarged and improved'—issued by the authorized British publishers, Sampson Low, Son and Co. The Library also possesses a set of the 'Wind and Current Charts' and an edition of the 'Sailing Directions.)

The book itself is described in Maury's own introduction as being concerned with presenting, in an interesting and instructive manner, "a philosophical account of the winds and currents of the sea, of the circulation of the atmosphere and ocean, of the temperature and depths of the sea, of the wonders that lie hidden in its depths, and of the phenomena that display themselves at its surface.... its salts, its waters, its climates and its inhabitants, and of whatever there may be of general interest in its commercial uses or industrial pursuits".

The twenty-two chapters often seem haphazard but are packed with information and comment about the ocean and the atmosphere above it. After an introductory chapter on the sea and the atmosphere there are two chapters on the Gulf Stream—"the weather breeder". It is interesting to find that Dr. Franklin proposed to use sea temperature as a navigational aid, especially in the Gulf Stream area near the American coast, and that Rhode Island captains, by knowing how to avoid the Gulf Stream, were able to make better east–west Atlantic crossings than English captains. The currents of the atmosphere (trade winds, calm belts, and land and sea breezes) are then described and discussed at length in several chapters, although not always correctly. It is interesting to see red dust from the desert being quoted as a ,"tally of the invisible air". The currents of the sea are next discussed, with an interesting account of the specific gravity of the sea, the salts of the sea, icebergs, whales and microscopic animalcules. Chapters on cloud at sea and on the interaction of winds and land masses are then followed by an account of the difficulties of deep sea soundings and the practical means of overcoming them. There are also descriptions of the types of minute shells obtained from the depths, and their microscopic examination. (At one time Maury had in mind a 'picture chapter of the sea' and published drawings of microscopic organisms in the 7th and 8th editions of the Sailing Directions.)

Winds over sea routes and monsoons are then treated; with chapters also on sea temperatures and tide rips. Sperm whales are associated with warm water currents as shown on a chart of 'Sea drift and Whales,' while the right whale is found in cold water. Storms, hurricanes and typhoons are then discussed; some of the last chapters deal with winds in the southern hemisphere, and the climate of Antarctic regions. The book concludes with a chapter on temperature at different depths.

Professor Leighly points out that Maury presents in convenient form a map of the temperature of the surface water of the Atlantic (Figure 9) and also a map of the relief of the bottom of the Atlantic. Such maps were produced from original material prepared under Maury's direction for the 'Wind and Current Charts' and the 'Sailing Directions,' and represented an important step forward in the knowledge of the sea. Important information is also given on the sediments of the deep sea as shown in samples brought up by Brooke's sounding apparatus. The scientific weaknesses of the book lie in the more general speculations and hypotheses, and there the reader must weigh each paragraph carefully and distinguish fact from fancy. Thus an American meteorologist Frank Waldo said in 1893, "Maury showed his strength by collecting and mapping the normal winds of the oceans but shows his weakness in speculating on a philosophy of their origin". Although as a scientific treatise the Physical Geography fell below the level of the best contemporary knowledge, the rhetorical devices of popular writing made it a readable book for many. Its Biblical quotations and its many references to natural phenomena as examples of divine design even resulted in a favourable review in the *Christian Examiner* of 1856.

The original book contained several maps and tables and these have been well reproduced in this edition—in some cases in a slightly smaller form than the original to avoid 'fold out' maps. A useful index has been added by the editor who has also explained the minor changes which he has made to help the reader of today. The book can be recommended as an authoritative republication of a work by a famous American pioneer of oceanography and meteorology.

W.S.G.

HONOUR

H.M. The Queen has approved the award of the Polar Medal to Mr. M. J. Blackwell for service as Senior Scientific Officer with the British Antarctic Survey during the 1959–60 season.

METEOROLOGICAL OFFICE NEWS

Gift from the Ghana Meteorological Services to the Meteorological Office

The Meteorological Office has received from the Ghana Meteorological Services, through the Office of the High Commissioner for Ghana in London, a gift of a wood carving of a drummer and talking drums, together with a strip of 'Kente' cloth, the Ghana national costume. The carving, which is about 10 inches high, is illustrated in Plate IV.

This gift has been made in appreciation of the services of the Meteorological Office Training School to the Ghana Meteorological Services in recent years and to mark the occurrence in 1960 of the 25th anniversary of the Training School.

In the letter accompanying the gift, Mr. F. A. A. Acquaah, the Director of the Ghana Meteorological Services, says "The talking drums, by tradition, are used both as means of communication and on festive occasions in Ghana. It is my sincere wish that the sound of these drums and the bright colours of the 'Kente' perpetuate the close, warm and fruitful relations that exist between the United Kingdom Meteorological Office and the Ghana Meteorological Services."

I have accepted this gracious gift on behalf of the Office and I reciprocate the good wishes of the Ghana Meteorological Services. This splendid work of art will form a unique addition to our collection of historic objects and will be put on display, at first in the Headquarters at Bracknell and later at the Training School. O. G. SUTTON

Retirement.—The Director-General records his appreciation of the services of:

Mr. H. L. Wright who retired from the Meteorological Office on 30 November 1963 after more than 36 years service. He was educated at Roborough School, Eastbourne and Kings College, London. After leaving Kings College with a first class honours degree in mathematics and a Drew gold medal he joined the Meteorological Office in 1927. Here he developed an interest in suspensoids in the atmosphere and their effect upon visibility. From Kew he was posted first to Eskdalemuir and then to Larkhill. His interest in visibility continued and led to a number of important papers. For this work he received the Buchan Prize of the Royal Meteorological Society in 1941.

In 1936 he was posted to Iraq where he served for two years. Following some short spells of duty with the Admiralty, the outbreak of war led to his return to the Middle East in 1940 where he served at various places until 1945, first as a civilian and later as a Squadron Leader. He was mentioned in dispatches in 1945. During this Middle East tour Mr. Wright was, for a time, Director of the Palestine Meteorological Service.

On return to the United Kingdom he was placed in charge of the branch responsible for supervising the upper air stations. This posting lasted for nearly three years and was followed by a spell of nearly the same length in the personnel branch. There followed two years in charge of one of the branches serving the Royal Air Force. In 1952 Mr. Wright again went abroad, this time as Chief Meteorological Officer at SHAPE (Supreme Headquarters Allied

Powers in Europe). On completion of the normal two year tour in that post he returned to this country with promotion to Senior Principal Scientific Officer to fill the post of Assistant Director (Staff and General). His last posting came with the reorganization of the Office in 1957 when he was placed in charge of Techniques and Training. It was fitting that after a career in which the early years were distinguished by his personal contributions to the science of meteorology his final post should have seen him in charge of the technical education of the younger members of the Office. His final year of service also saw him elected as a Vice-President of the Royal Meteorological Society in recognition of his services as Editor of *Weather*.

Throughout his career as a professional meteorologist 'Lionel' (I never heard him addressed by his first name) maintained an unruffled and urbane exterior. He was always ready to assist others. He has elected to retire from the Office at an earlier age than most and his many friends and colleagues will hope that he will enjoy a long and happy retirement.

A.C.B.

CORRIGENDA

Meteorological Magazine, January 1964, page 8, line 24: for 'decreased' read 'increased'; page 12, Table I (*a*), line 6: delete 'Date of absolute minimum' and insert 'Date/time (GMT) of absolute minimum'; under columns headed '4 inches' and 8 'inches' after '24th' add '0900'.

Meteorological Magazine, March, 1964, page 74: under Figure 3, for 'July' read 'January'.

OFFICIAL PUBLICATION

SCIENTIFIC PAPER

No. 18—Airflow around a model of the Rock of Gibraltar, by J. Briggs, B.A.

For certain adverse winds, those from south-east through south to south-west, severe turbulence in the lee of the Rock of Gibraltar can affect the runway at North Front, and also the approaches to the runway. This paper gives an account of wind-tunnel work designed to map out the areas of strong turbulence near the runway for these adverse winds.

Diagrams are presented which indicate the likely areas of rough and smooth air, at heights between 500 and 3500 feet and for winds between south-east and south-west, near the runway. The diagrams are based on observations of the fluctuations of smoke in the airflow around a scale model of the Rock.

A theoretical discussion of the relation of model airflow to real airflow suggests that the diagrams can give useful indication of the turbulent areas in the lee of the actual Rock.

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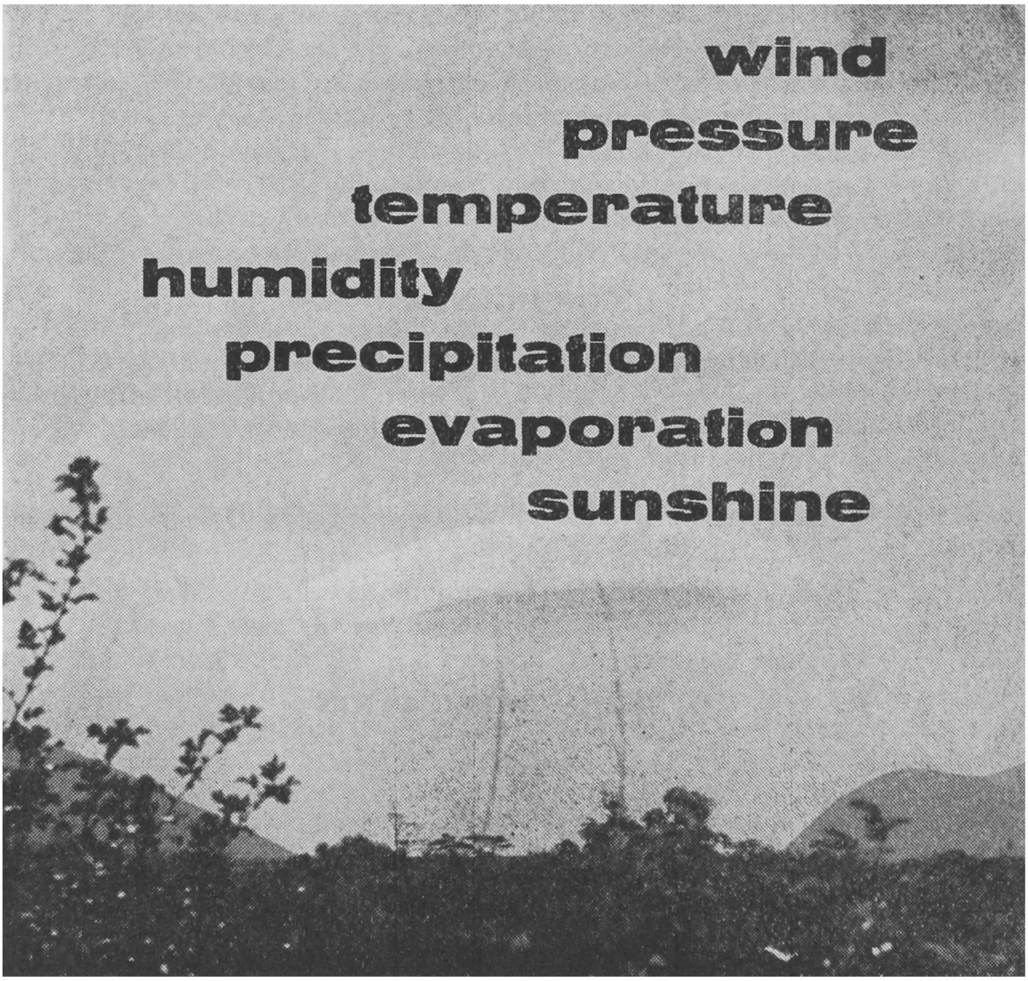

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